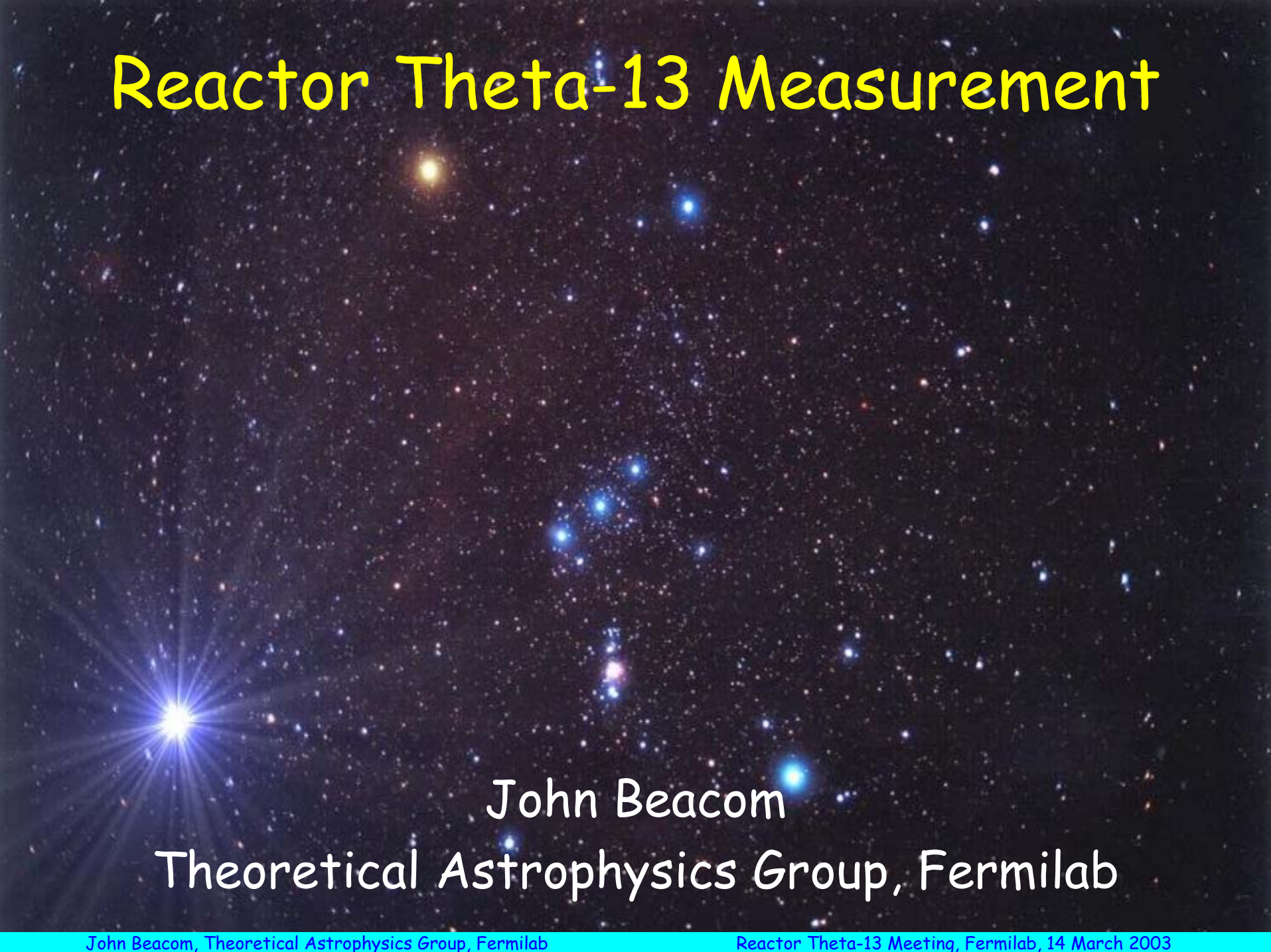
Reactor Theta-13 Measurement



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Basic Assumptions

$E_\nu \simeq 4$ MeV, varies by $\times 2$ or $\div 2$

θ_{13} : $\sin^2 2\theta_{13} \leq 0.1$, $\delta m^2_{13} \simeq 3 \times 10^{-3} eV^2$

θ_{12} : $\sin^2 2\theta_{12} \simeq 0.9$, $\delta m^2_{12} \simeq 7 \times 10^{-5} eV^2$

1.65km : maximal oscillations at peak

oscillation phase = 90 degrees

FAR: 1.65 km, NEAR: 165 m

Goal is to work to the 1% (absolute) level

Distance Uncertainty

- Flux error is double distance error

  FAR: 8 m is enough

  NEAR: need 0.8 m (properly weighted)

- Distance uncertainty is *differential* between NEAR and FAR

- Distance uncertainty doesn't matter in oscillation probability

NEAR Detector Sub-Oscillations

FAR : $\text{Rate} \sim 1 - \sin^2 2\theta_{13} \sin^2(90^\circ)$

NEAR : $\text{Rate} \sim 1 - \sin^2 2\theta_{13} \sin^2(9^\circ)$

$$\text{Ratio} \simeq 1 - \sin^2 2\theta_{13} \left[\underset{1}{\sin^2(90^\circ)} - \underset{0.025}{\sin^2(9^\circ)} \right]$$

Could matter for a farther near detector

FAR Detector Sub-Oscillations

$$\text{Effect} \sim 1 - 0.9 \sin^2\left(\frac{1.27 \cdot 7 \times 10^{-5} \cdot 1650}{4}\right)$$

$$\simeq 2^{\circ}$$

Deviation $\simeq 0.001$

Ok, but can reach 0.01 with slight shifts in the assumed parameters

Cautions

- Could be oscillations to sterile neutrinos
- Maximize spectrum distortion versus rate to get a clean signature
- NEAR: high rate good but careful about distance error
- FAR: higher backgrounds effect response, which makes it different from the NEAR detector
- Many reactors complicate signals/backgrounds
- Backgrounds and oscillations maximal at low E

Cross Section Errors

- Radiative corrections ~ few percent
  Recoil + weak magnetism ~ few percent

- Recoil neutron ~ E^2/M ~ tens of keV
  Spectrum correction up to 10%

- Miscalibration at a few keV causes a flux error

- Want to get right absolute calibration

- Can reduce cross section error to about 0.2%

Finite Event Size

- Detected events are not pointlike
- Event size << reactor-detector distance
- But event size not so small compared to detector size or position resolution
- Positron travels just a few cm, but neutron cloud has radius of about 5 cm at one sigma (and is displaced); comment on Bugey segmentation
- Angular distributions are not isotropic

More On Correlations

- Position-neutron detection efficiency variation with energy of each
- Containment correlated to separation (differential if detectors not same size)
- Near detector size is ~ 1 degree and reactor size can be ~ 3 degrees; this affects event containment at the edges
- Note 15 cm / 3 m is 5%, but turns into 15% in the detected rate

Final Comments

- Reactor is the way to go for theta-13; cosmology may get to normal vs. inverted first
- It should be possible to reach 1%, and it will be more compelling if it is an absolute error; need to improve over Bugey by a factor 4 or so
- Decisive signal and systematic control needed since these results are a crucial input to the ~ $billion neutrino factory decision
- Careful about cross section details; see Vogel and Beacom, PRD 60, 053003 (1999)